Calculation of the Cross-sectional Areas of Circuit Live Conductors and Cables

- Voltages

All specifications, design and calculations should use 230/400V voltage figures when the supply comes directly from the main. However if the supply comes from consumer local substation then 240/415 V figure is used.

The factors that influence the current rating of any cable are:

1. The design current – the cable must carry the full load current;
2. The type of cable – PVC, XLPE,, copper conductors or aluminium conductors;
3. The installed conditions – clipped to a surface or installed with other cables in a trucking;
4. The surrounding temperature – cable resistance increases as temperature increases and insulation may melt if the temperature is too high;
5. The type of protection – for how long will the cable have to carry a fault current?

- Allowable Voltage drops in the cables:

Regulation states that the drop in voltage from the supply terminals to the fixed current-using equipment must not exceed 3% for lighting circuits and 5% for other uses of the mains voltage. That is, a maximum of 6.9 V for lighting circuits and 11.5 V for other uses on a 230 V installation.

To determine the minimum conductor cross-sectional area of the live conductors of a particular circuit that can be tolerated the designer must:

(a) Determine the method of installation according to the standard table (3-4).

(b) Establish what is the expected ambient temperature (t_a ºC). This gives the relevant value of Ca (or K1).

(c) Decide whether the circuit is to be run singly or be bunched or grouped with other circuits and, how many other circuits. The decision taken gives the relevant value of C_g (or K2).

(d) Decide whether the circuit is likely to be totally surrounded by thermally insulating material . If this is to be the case, Ci (or K3) is taken to be 0.5.

(e) Determine the design current (I_b) of the circuit.

(f) Choose the type and nominal current rating (In) of the associated overcurrent protective device. For all cases In must be equal to or greater than Ib.

Establish whether it is intended the overcurrent protective device is to give:
(i) overload protection only, or
(ii) short circuit protection only, or
(iii) overload and short circuit protection.

The intended function of the overcurrent protective device not only determines
whether Ib or In is used as the basis for calculating the minimum cross sectional area of the live conductors but also influences the value of Ca that is to be used in the calculations.

(g) Establish the maximum voltage drop that can be tolerated.

(h) Estimate the route length of the circuit.

The general method for the determination of the minimum conductor cross sectional areas that can be tolerated now described does not apply to cables installed in enclosed trenches. These are considered later. The general method is as follows:

The cable rating, denoted I_t , may be determined as follows:

First calculate the current I_t where:

$$I_t = \frac{\text{Current rating of protective device}}{\text{Any applicable correction factors}}$$

$$I_t = I_x \times \frac{1}{C_a} \times \frac{1}{C_g} \times \frac{1}{C_i} \times \frac{1}{C_d} \text{ A}$$

C_a = the ambient or surrounding temperature correction factor,

.

C_g = the grouping correction factor.

.

C_d (or C_c) = the 0.725 correction factor to be applied when semi-enclosed fuses protect the circuit

C_i = the correction factor to be used when cables are enclosed in thermal insulation.

EXAMPLE 1: A 3 - core, copper conductor belted type XLPE cable has a cross sectional area of 240 mm^2. If four cables of this type are laid together on a perforated cable tray at 40 ºC ambient temperature, find the derating factor and the new current carrying capacity of the cable.

Solution:

- Determine the method of installation from Table (3-4) (Lecture No.3). ⟹ E
- Determine the current carrying capacity of the 240 mm2 XLPE cable from Table (3-12) for installation method E , this gives : I = 564 A at 30 ºC .
- Determine the grouping factor for four cables from Table (3-17) for method of installation E with number of trays =1 and number of cables = 4 ⟹ Cg = 0.79.
- Determine the correction factor for the difference in temperature (ambient temp .-40 ºC) from Table (3-18) ⟹ Ca = 0.91 .
- Calculate the correction factor :

$$C = Ca \,.Cg = 0.91 \times 0.79 = 0.718$$

= Derating factor

Hence the new current carrying capacity of the cable will be:

$$I_t = 564 \times C = 564 \times 0.718 = 405 \text{ A}$$

EXAMPLE 2 : A circuit is to be installed using 3x 2.5 mm^2 (twin and earth) 70°C PVC cable, it is 32 metres long and protected by a BS 88 fuse. The load to be supplied is a 4.2 kW hot water cylinder; the circuit is to be installed in minitrunking containing one other circuit at an ambient temperature of 35°C. Maximum permissible volt drop is 7 V. Calculate the minimum cable that may be used.

Solution
Design current

$$I_b = \frac{P}{V}$$

$$\frac{4.2 \times 1000}{230} = 18.26 \text{ amperes}$$

Protective device $I_n \ (\geq 18.26)$

nearest protective device rating is 20 amperes.

In the example, the cable is installed in plastic trunking. From Table 3- 4 Installation methods, B1 and B2 matches the example. The cable is installed in trunking which will contain one other circuit. Correction factor for grouping (C_g *or* K_2) is required from Table(3-13). It can be seen that for two circuits in one enclosure a factor of 0.8 must be used.

The ambient temperature is 35°C. A correction factor for ambient temperature (C_a) from Table (3-18) must be used. PVC cable at 35 , C_a factor of 0.94.
Using these factors, it is now possible to calculate the minimum size conductors required for this circuit.

$$I_t \geq \frac{I_n}{C_a \times C_g}$$

$$I_t \geq \frac{20}{0.8 \times 0.94} = 26.59 \text{ A}$$

- This is the minimum value of current that the cable must be able to carry. From Table (3-5) columns 4 and 5, it can be seen that a 4mm^2 cable has an I_t (current carrying capacity) of 30 amperes.

- A cable with 4mm^2 live conductors will carry the current in these conditions without overheating, but will it comply with the voltage drop requirements?

From Table (3-23) columns 1 and 3, it can be seen that 4 mm^2 cable has a voltage drop of 9.56 (mV/A/m) or millivolts × loadcurrent × length of circuit. As the value is in millivolts, it must be converted to volts by dividing by 1000. The circuit length is 32 metres and the load current is 18.26 amperes.

Calculation

$$\frac{mV/A/m \times I \times L}{1000} = \frac{9.56 \times 18.26 \times 32}{1000} = 5.57 \text{ V}$$

The voltage drop in this cable will be 6.42 V which is acceptable as the maximum permissible for the circuit is 7 V.